(Translation)

AMENDMENT

(Amendment under the Article 11 of the Law Concerning the International Application of the PCT and Related Matters)

To: Patent Office Examiner Mr. HORIBE Shuhei

1. International Application Number: PCT/JP03/11968

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4. Object of Amendment: The Specification and the Claims

5. Contents of Amendment:

(1) Line 11 in Page 2 in the Specification:

Replace "by constituting the light emitting electrode by whiskers of a metal oxide" by " by constituting the light emitting electrode and the cold cathode respectively by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD".

(2) LL. 14-15 in Page 2 in the Specification:

Replace "the light emitting electrode is constituted by a metal oxide structure having whiskers of a metal oxide." by "the light emitting electrode and the cold cathode are respectively constituted by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD."

(3) LL. 12-16 in Page 3 in the Specification:

To be deleted.

LL. 18 and 16 in the same Page:

Replace "1 to 10" by "1 to 8" respectively.

(4) Line 3 in Page 4 in the Specification:

Add "15.The light emitting device according to 12, wherein an electron accelerating electrode is provided between the cold cathode and the light emitting electrode.

16.The light emitting device according to any one of 1 to 8 & 11 to 15, wherein the light emitting device emits light in an ultraviolet ray region."

(5) LL. 16-17 in Page 4 in the Specification:

Replace "a light emitting electrode" by "a light emitting electrode and a cold cathode".

Replace "is constituted by a metal oxide structure having whiskers of a metal oxide." by "are respectively constituted by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD."

(6) LL. 5-6 in Page 14 in the Specification:

Delete "is not particularly limited and any material which is ordinarily used as the cold cathode can be used. As for preferable materials in this occasion".

(Translator's Note: In the English text, it is necessary to replace "The material" in Line 5 in the Page by "As the material" in order not to change the meaning.)

LL. 9-13 in the same Page:

Delete "Further, as for other preferable materials, carbonaceous material such as a carbon nanotube, fullerene, diamond grains, graphite grains and a carbon fiber are listed."

(7) LL. 1-5 in Page 17 in the Specification:

Replace "has been explained; however, it goes without saying that any of other materials such as carbonaceous material, for example, a carbon nanotube, fullerene, diamond grains, graphite grains and a carbon fiber can be used as a material constituting the cold cathode. Further, as the container containing the cold cathode and

the light emitting electrode," by "has been explained. As the container containing the cold cathode and the light emitting electrode,".

(8) Claim 1:

Replace "the light emitting electrode is constituted by a metal oxide structure having whiskers of a metal oxide." by "the light emitting electrode and the cold cathode are respectively constituted by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD."

(9) Cancel Claims 9 and 10 and add Claims 15 and 16 written in the substituted sheets.

(10) Claims 11 and 12.

Replace "Claims 1 to 10" by "Claims 1 to 8" respectively.

6. List of the attached documents:

(1) Substituted sheets of the Specification:

PP. 2-4, 14 and 17.

(2) Substituted Claims:

PP. 22-23.

(Translator's Note: Substituted sheets of the English Text corresponding to the above-mentioned amendment in the Japanese Specification are attached.)

cathode are disposed opposite to each other, the above-described problems can be solved by constituting the light emitting electrode and the cold cathode respectively by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD, to thereby achieve the present invention.

Namely, according to the present invention, following constitutions are adopted.

1. A light emitting device, wherein a light emitting electrode and a cold cathode are disposed opposite to each other, wherein the light emitting electrode and the cold cathode are respectively constituted by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD.

2. The light emitting device according to 1, wherein a band gap of the metal oxide constituting the whiskers is from 1.5 to 7.7 eV.

3. The light emitting device according to 1 or 2, wherein a diameter of a cross-section of an approximate circle of the whisker is from 0.01 to 100 μm and a ratio of length of the whisker to the diameter of the cross-section of the approximate circle of the whisker is from 1 to 10000.

4. The light emitting device according to any one of 1 to 3, wherein the whiskers are present in a density of from 0.1 to 10000 pieces per area of 10 μmx10 μm on a surface of the metal

oxide.

5. The light emitting device according to any one of 1 to 4, wherein the whiskers comprise an element different from that of a main material which constitutes the whiskers.

6. The light emitting device according to any one of 1 to 5, wherein the whiskers can be obtained by allowing the metal oxide to be epitaxially grown on a surface of a substrate.

7. The light emitting device according to any one of 1 to 6, wherein zinc oxide is used as the main material which constitutes the whiskers.

8. The light emitting device according to any one of 1 to 7, wherein a light emitting electrode is constituted by the metal oxide structure in which spaces between whiskers are filled with a material selected from among an organic substance, an inorganic substance and a metal.

11. The light emitting device according to any one of 1 to 8, wherein the light emitting electrode and the cold cathode are disposed in a vacuum chamber or a container having a gas sealed therein.

12. The light emitting device according to any one of 1 to 8, wherein the light emitting electrode in a planar shape and the cold cathode in a planar shape are disposed opposite to each other in the container.

13. The light emitting device according to 12, wherein a reflecting plate is provided on one side face of a space defined

by the light emitting electrode and the cold cathode.

14. The light emitting device according to 11, wherein the light emitting electrode is disposed on an inner surface of the container and the cold cathode is disposed in a center portion of the container.

15.The light emitting device according to 12, wherein an electron accelerating electrode is provided between the cold cathode and the light emitting electrode.

16.The light emitting device according to any one of 1 to 8 & 11 to 15, wherein the light emitting device emits light in an ultraviolet ray region.

Brief Description of the Drawings

FIG. 1 is a schematic diagram showing an example of an atmospheric open type CVD apparatus for producing a material which constitutes a light emitting electrode or a cold cathode of a light emitting device according to the present invention.

FIG. 2 is a schematic diagram showing another example of an atmospheric open type CVD apparatus for producing a material which constitutes a light emitting electrode or a cold cathode of a light emitting device according to the present invention.

FIG. 3 is a schematic diagram showing an example of a light emitting device according to the present invention.

FIG. 4 is a schematic diagram showing another example

of a light emitting device according to the present invention.

FIG. 5 shows schematic diagrams of still another example of a light emitting device according to the present invention, wherein (A) shows a perspective diagram thereof and (B) shows a cross-sectional diagram thereof.

FIG. 6 is a schematic diagram showing further still another example of a light emitting device according to the present invention.

Best Mode for Carrying Out the Invention

The present invention is characterized in that a light emitting electrode and a cold cathode of a light emitting device in which the light emitting electrode and the cold cathode are disposed opposite to each other, are respectively constituted by a metal oxide structure having whiskers of a metal oxide grown on a surface of a substrate by CVD.

The whisker according to the present invention means an article having a structure in an approximate rod shape in which a diameter of a cross-section of an approximate circle is from 0.01 to 100 μm (average value; hereinafter, the same holding true) and length to the diameter of the cross-section of the approximate circle (aspect ratio) is 1 or more. Further, the length of the whisker means a length of from a position (base portion) on which the whisker is substantially protruded from a surface to a tip portion and the diameter of the cross-section

of the approximate circle is measured at a position of half the length of the whisker. As far as the diameter of the cross-section of the approximate circle is concerned, firstly, a cross-section area is obtained by using a known method, for

fill-fixing the space between whiskers, an epoxy resin, a DFK resin, a xylene resin, a guanamine resin, a diallyl phthalate resin, a vinyl ester resin, a phenol resin, an unsaturated polyester resin, a furan resin, polyimide, poly(p-hydroxybenzoic acid), polyurethane, a maleic acid resin, a melamine resin, a urea resin and the like are listed. As for such elastomers to be used for fixing the whiskers, natural rubber and synthetic rubbers such as a butadiene rubber, a silicone rubber, a polyisoprene rubber, a chloroprene rubber, an ethylene-propylene rubber, a butyl rubber, an isobutylene rubber, a styrene-butadiene rubber, a styrene-isoprene-styrene block copolymer rubber, an acrylic rubber, an acrylonitrile-butadiene rubber, a hydrochlorinated rubber, a chlorosulfonated polyethylene rubber and a polysulfide rubber are listed. Other than these rubbers, polytetrafluoroethylene, a petroleum resin, an alkyd resin and the like can be used.

The light emitting device according to the present invention is constituted by allowing the light emitting electrode comprising the metal oxide structure having the whiskers of the metal oxide as has been described and the cold cathode to be disposed opposite to each other in the vacuum chamber or the container having the gas sealed therein.

As the material to constitute the cold cathode of the light emitting device, the metal oxide structure having the

whiskers(including the whiskers comprising the element different from the main material) to be used in the light emitting electrode, an article in which the tip portions of the whiskers of the metal oxide structure are covered with an electrically conductive material and the like can be used.

Next, the light emitting device according to the present invention is further described with reference to drawings; however, the present invention is not limited to embodiments to be described below.

FIG. 3 is a schematic diagram showing an example of a light emitting device according to the present invention. In a light emitting device 1, a cold cathode 3 and a light emitting electrode 4 are disposed opposite to each other in a vacuum glass tube 2. The cold cathode 3 is constituted by a material in which whiskers 12 of a metal oxide are formed on a surface of a metal substrate 11 by an atmospheric open type CVD method. Further, the light emitting electrode 4 is constituted by a material in which a transparent electrically conductive film 14 comprising ITO, SnO_2, ZnO or the like is formed on a surface of a glass substrate 13 and, then, whiskers 15 of a metal oxide

emitting electrode 4, to thereby apply a bias voltage. Further, a reflective plate 37 such as a mirror is provided on one side face of a space defined by the cold cathode 3 and the light emitting electrode 4 and a light semi-transmissive plate 38 such as a half-mirror is provided on another side thereof.

In the light emitting device 31, electrons emitted from tip portions of the whiskers 34 of the cold cathode 3 are bombarded with the whiskers 36 of the light emitting electrode 4 and, then, allow the free exciton luminescence having an energy approximately equal to the band gap of the metal oxide constituting the whiskers to be generated and, subsequently, the resultant light is reflected by the reflecting plate 37 provided on the side face, transmitted through the light semi-transmissive plate 38 on another side face and emitted in a direction denoted by an arrow mark.

In the above-described embodiments, an example in which the cold cathode of the light emitting device is constituted by the metal oxide structure having the whiskers of the metal oxide in a same manner as in the light emitting electrode has been explained.

As the container containing the cold cathode and the light emitting electrode, the container having a gas sealed therein may of course be used in place of the vacuum chamber.

EXAMPLES

Next, the present invention will be described in detail with reference to examples; however, the present invention is not limited thereto.

In a light emitting device according to the present invention, a metal oxide structure having whiskers of a metal oxide to be used as a material which constitutes a light emitting electrode or a cold cathode can be produced by an ordinary method by using an atmospheric open type CVD method as shown in FIG. 1 or 2.

Example 1

$Zn(C_5H_7O_2)_2$ as a raw material was vaporized at a vaporizing temperature of 115°C in a N_2 gas flow rate of 1.2 dm^3/min by using an apparatus as shown in FIG. 1 and, then, blown on a transparent glass substrate which was coated with a transparent electrically conductive film and heated at 550°C from a nozzle in a slit shape, to thereby grow ZnO whiskers oriented to <0001>. Such whiskers each having a length of 40 μm and a diameter of 2 μm were formed on a surface of the substrate in a dense state. The resultant article was defined as a light emitting